Appendix E

Wet Weather Model Calibration, Configuration, and Validation

The development of Total Maximum Daily Loads (TMDLs) for a pollutant requires an assessment of the pollutant load from a watershed to an impaired receiving waterbody. Wet weather sources of bacteria are generally associated with the wash-off of bacteria loads that have accumulated on the land surface during dry weather conditions. During wet weather conditions, or rainy periods, these bacteria loads are transported to a water body via precipitation runoff over the ground surface and/or through stormwater collection systems.

There is often a correlation between sources of bacteria and specific land use types. Specific land use types may have higher relative accumulation rates of bacteria, or may be more likely to deliver bacteria to water bodies through stormwater collection systems. The link between sources of bacteria and their impact on receiving water bodies may be assessed by developing and utilizing mathematical models. A model can be developed to simulate the build-up and wash-off of bacteria and the hydrologic and hydraulic processes that can affect the bacteria loads that may be transported to the water bodies from different land use types.

In order to assist with the analysis of the link between potential wet weather sources of bacteria in the Tecolote Creek watershed and instream bacteria concentrations, a model of the Tecolote Creek watershed was developed. Development of this model was based on available spatial, meteorological, geological, hydrological, and water quality data available for the watershed, and builds upon previous technical approaches for modeling bacteria sources in the San Diego Region. This report summarizes the process for developing the model for the Tecolote Creek watershed.

The Tecolote Creek watershed model that has been developed is a direct application of the regionally calibrated models from the *Total Maximum Daily Loads for Indicator Bacteria Project I – Beaches and Creeks in the San Diego Region* (hereafter referred to as Bacteria TMDL Project I) (San Diego Water Board, 2007). For Bacteria TMDL Project I three watersheds (Santa Margarita River, Tecolote Creek and Rose Creek) were configured for San Diego Region-wide calibration, since data in these watersheds were plentiful. Regional calibration involved determining a single set of hydrologic and water quality parameters that closely predicted observed stream flow and bacteria concentrations in all watersheds of the region. Using the calibrated region-wide model, thirteen watersheds were modeled for assessment of bacteria loads to impaired waterbodies. Data for these thirteen watersheds were used to compare with model output during calibration and validation of the Bacteria TMDL Project I models (San Diego Water Board, 2007).

The Tecolote Creek watershed was not modeled for assessment of bacteria loads to the impaired creek during Bacteria TMDL Project I because watersheds draining to impaired bays were excluded from that study. This current project addresses the bacteria loads to Tecolote Creek, which ultimately discharge into Mission Bay. This process involves model configuration, subwatershed delineation, application of the regional parameters to the Tecolote Creek watershed, continuous simulation of flow and water quality, and comparison of model results to observed flow and water quality data.

The United States Environmental Protection Agency's (USEPA's) Loading Simulation Program in C++ (LSPC) (Shen et al., 2004; USEPA, 2003a) was selected to simulate the hydrologic processes and bacteria loading to receiving waterbodies in the Tecolote Creek watershed. LSPC is a component of the USEPA's TMDL Modeling Toolbox (Toolbox) (USEPA, 2003b), which has been developed through a joint effort between the USEPA and Tetra Tech, Inc. The Toolbox integrates a geographical information system (GIS), comprehensive data storage and management capabilities, a dynamic watershed model (a re-coded version of the USEPA's Hydrological Simulation Program – FORTRAN [HSPF]) and a data analysis/post-processing system into a convenient PC-based windows interface that dictates no software requirements. Similar models have been successfully calibrated and applied in Southern California for multiple pollutants, including watersheds of Santa Monica Bay (Los Angeles Water Board, 2002), Ballona Creek (Ackerman et al., 2005; Los Angeles Water Board, 2005a), Los Angeles River (Los Angeles Water Board, 2005b), San Gabriel River (Tetra Tech, Inc, 2005a), San Jacinto River (SAWPA, 2003; Tetra Tech, Inc, 2005b), and multiple watersheds draining to impaired beaches of the San Diego Region for Bacteria TMDL Project I (San Diego Water Board, 2007). Many of these models were applied to support TMDL development and the projects are in varying stages of the TMDL approval process (including several adopted TMDLs).

This document describes the methodologies employed for the modeling of wet weather flow of precipitation runoff and bacteria concentrations for Tecolote Creek. Development and application of the watershed model to address the project objectives involved a number of important steps:

- Watershed Delineation
- Configuration of Key Model Components
- Model Validation

Detailed discussions of these steps are provided in the following sections.

C.1 Watershed Delineation

Watershed delineation refers to the subdivision of a watershed into smaller, discrete subwatersheds for modeling and analysis. Delineation of the watersheds in the San Diego Region was performed in the Bacteria TMDL Project I (San Diego Water Board, 2007), primarily based on the stream networks and topographic variability, and secondarily on the locations of flow and water quality monitoring stations, consistency of hydrologic factors, land use consistency and existing watershed boundaries (based on CALWTR 2.2 watershed boundaries).

During the Bacteria TMDL Project I, the San Diego Region was divided into sixteen watersheds for model configuration, which were further delineated into numerous subwatersheds for modeling and analysis. Three of these watersheds (Santa Margarita River, Tecolote Creek, and Rose Creek) were included for San Diego Region-wide model calibration purposes due to an abundance of flow and/or water quality data in these watersheds. The calibrated region-wide model was then used to calculate TMDLs and estimate existing bacteria loading to the remaining thirteen watersheds (San Diego Water Board, 2007).

As described above in the introduction, the Tecolote Creek watershed was not modeled for assessment of bacteria loads to the impaired creek during Bacteria TMDL Project I because watersheds draining to impaired bays were excluded from that study. This current project addresses the bacteria loads to Tecolote Creek, which ultimately discharge into Mission Bay. To quantify these loads, the Tecolote Creek watershed delineation from Bacteria TMDL Project I was refined in order to capture all available monitoring stations. The Tecolote Creek watershed was delineated into six subwatersheds and is illustrated in Figure C-1. The size of the entire watershed is approximately 10 square miles.

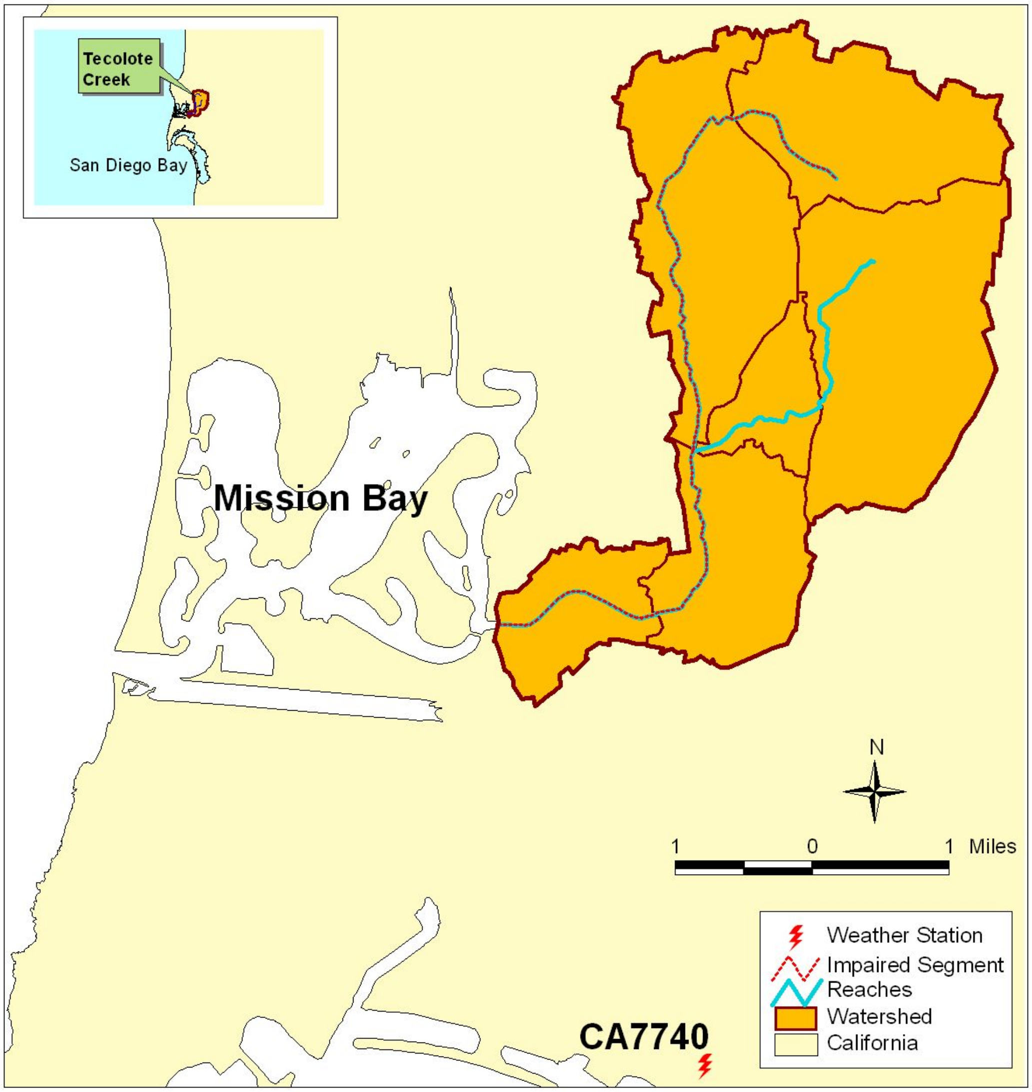
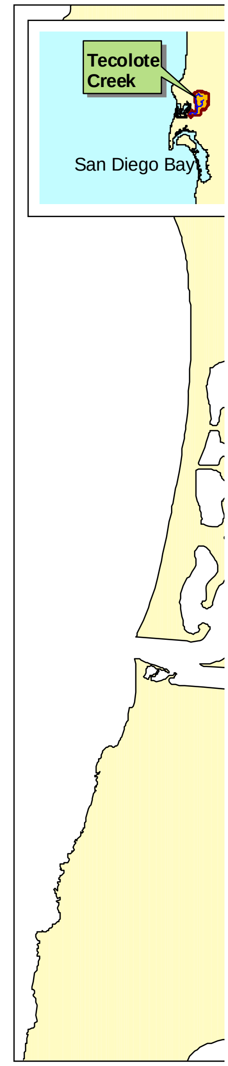


Figure C-1. Tecolote Creek Watershed



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C.2 Configuration of Key Model Components

Configuration of the LSPC watershed model takes into consideration five major components:

- Meteorological data;
- Land use representation;
- Hydrologic representation;

- Pollutant representation; and
- Waterbody representation.

These components provide the basis for the LSPC model's ability to estimate flow and pollutant loadings. Detailed discussions about the development of each component for the LSPC model are provided in the following subsections.

C.2.1 Meteorology

Meteorological data are a critical component of the watershed model. Meteorological data essentially drive the LSPC model. Rainfall and other parameters are key inputs to LSPC model's hydrologic algorithms. The LSPC model requires an appropriate representation of precipitation and potential evapotranspiration.

In general, hourly precipitation (or finer resolution) data are recommended for nonpoint source modeling. Therefore, only weather stations with hourly-recorded (or finer resolution) data were considered in the precipitation data selection process. Rainfall-runoff processes for each subwatershed were driven by precipitation data from the most representative station. These data provide necessary input to LSPC algorithms for hydrologic and water quality representation.

Meteorological data have been accessed from several sources in an effort to develop the most representative dataset for Tecolote Creek based on geographic location, period of record, and missing data. Hourly rainfall data were obtained from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA) for the San Diego International Airport, Lindbergh Field (COOP ID #047740), for the period of January 2000 to September 2005 for use in the model simulations (Figure C-1). Hourly evapotranspiration data were obtained from the California Irrigation Management Information System (CIMIS).

C.2.2 Land Use Representation

The LSPC model requires a basis for distributing hydrologic and pollutant loading parameters. Hydrologic variability within a watershed is influenced by land surface and subsurface characteristics. Variability in pollutant loading is highly correlated to land use practices. Land use representation provides a basis for distributing land surface and subsurface characteristics and pollutant loading characteristics throughout a watershed.

Land use representation was based on the San Diego Association of Governments (SANDAG) 2000 land use dataset that covers San Diego County. Although the multiple categories in the land use coverage provide much detail regarding spatial representation of land use practices in a watershed, such resolution is unnecessary for watershed modeling if many of the categories share common hydrologic or pollutant loading characteristics. Therefore, many land use categories from the SANDAG land use data set were consolidated with similar classifications, resulting in thirteen land use categories used for developing the LSPC model. Selection of these thirteen land use categories was based on the availability of monitoring data and literature values that could be used to characterize individual land use contributions and critical bacteria-contributing practices associated with different land uses. For example, multiple urban categories were represented independently (e.g., high density residential, low density residential and commercial/institutional), whereas forest and other natural categories were consolidated. Table C-1 presents the land use categories and distribution for the Tecolote Creek watershed.

Table C-1. Land use areas

Land Use Category	Area (square miles)	Fraction
Low Density Residential	4.826	48.2%
High Density Residential	0.776	7.8%
Commercial/ Institutional	1.878	18.8%
Industrial/ Transportation[1]	0.356	3.6%
Military	0.027	0.3%
Parks/ Recreation	0.313	3.1%
Open Recreation	0.091	0.9%
Open Space	1.737	17.4%
Agriculture	0	0%
Dairy/ Intensive Livestock	0	0%
Horse Ranches	0	0%
Water	0	0%
Transitional	0	0%

LSPC algorithms require that land use categories be further divided into pervious or impervious land units for modeling. Precipitation can infiltrate into the subsurface on pervious land units, whereas precipitation cannot infiltrate into the subsurface on impervious land units. This division was made for the appropriate land uses (primarily urban) to represent impervious and pervious land units. The division was based on typical impervious percentages associated with different land use types from the Soil Conservation Service's TR-55 Manual (Soil Conservation Service, 1986) as summarized in Table C-2. The other eight land use categories are assumed to be 100% pervious.

Table C-2. Percent impervious for urban land uses (based on TR-55)

Land Use	Pervious Percentage	Impervious Percentage
Industrial/Transportation[2]	18%	72%
Low Density Residential	85%	15%
High Density Residential	35%	65%
Commercial/Institutional	15%	85%
Parks/Recreation	88%	12%

[1] Includes Caltrans areas.
[2] Ibid

C.2.3 Hydrology Representation

Hydrologic representation refers to the modules, or algorithms, in the LSPC model used to simulate hydrologic processes (e.g., surface runoff, evapotranspiration, and infiltration). Hydrology in the model was represented with the LSPC PWATER (water budget simulation for pervious land segments) and IWATER (water budget simulation for impervious land segments) hydrology modules, which are identical to those in HSPF. These hydrology modules were used to simulate the hydrology for pervious and impervious land units (Bicknell et al., 1996) in the LSPC model.

Designation of key hydrologic parameters in the PWATER and IWATER hydrology modules of LSPC were required. These parameters are associated with infiltration, groundwater flow, and overland flow. Robust hydrology calibration and validation were performed previously for gauged watersheds in the Bacteria TMDL Project I (San Diego Water Board, 2007). The regionally-calibrated parameter values derived from the Bacteria TMDL Project I modeling effort were input to the PWATER and IWATER hydrology modules to parameterize the current Tecolote Creek watershed model.

C.2.4 Pollutant Representation

Pollutant representation refers to the modules, or algorithms, in the LSPC model used to simulate pollutant loading processes (primarily accumulation and wash-off). Pollutant loading processes in the model for fecal coliforms (FC), total coliforms (TC), and *Enterococcus* (ENT) were represented using the LSPC PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) water quality modules, which are identical to those in HSPF. These modules simulate the accumulation of pollutants during dry weather conditions and the wash-off of pollutants during wet weather conditions (rainy periods or storm events) for pervious and impervious land units in the LSPC model.

Land use-specific accumulation rates and buildup limits were initially obtained from a study performed by the Southern California Coastal Water Research Project (SCCWRP) to support bacteria TMDL development of Santa Monica Bay (Los Angeles Water Board, 2002). These initial values from SCCWRP served as baseline conditions for water quality calibration; the appropriateness of these values to the San Diego Region was validated through comparison with local water quality data (San Diego Water Board, 2007). Because these buildup limits and accumulation rates have already been validated for the Bacteria TMDL Project I (San Diego Water Board, 2007), they were considered suitable for use in this smaller-scale modeling effort and were thus incorporated into the PQUAL and IQUAL water quality modules.

C.2.5 Waterbody Representation

Waterbody representation refers to modules, or algorithms, in the LSPC model used to simulate flow and pollutant transport through streams and rivers. Each delineated subwatershed is represented with a single stream assumed to be a completely mixed, one-dimensional segment with a trapezoidal cross-section. The National Hydrography Dataset (NHD) stream reach network was used to determine the representative stream reach for each subwatershed. Once the representative reach was identified, slopes were calculated based on digital elevation model (DEM) data and stream lengths measured from the new stream coverage. In addition to stream slope and length, mean depths and channel widths are required to route flow and pollutants through the hydrologically connected subwatersheds.

The Tecolote Creek concrete mainstream (bottom of watershed) channel dimensions, which were measured for estimation of gauged streamflows and urban runoff monitoring purposes, were obtained from Weston Solutions, Inc. (County of San Diego, 2005; Weston Solutions, Inc., 2006). The width and depth for the Tecolote Creek concrete mainstream channel was measured to be approximately 50 feet and 8.67 feet, respectively. The Tecolote Creek natural upstream channel depths and widths were estimated using regression curves that relate upstream drainage area to stream dimensions. To represent channel roughness, estimated Manning's roughness coefficients of 0.015 and 0.03 were applied to the concrete mainstream channels and the natural upstream channels, respectively.

C.3 Model Calibration and Validation

After the LSPC watershed model was configured, model calibration and validation was performed. Model validation for hydrology and water quality occurs after model calibration. The entire model calibration and validation process is generally a two-phase process, with hydrology calibration and validation completed before repeating the calibration and validation process for water quality. Model calibration refers to the adjustment or fine-tuning of modeling parameters until the model is able to reproduce previous observations from a particular location and time period. Subsequently, model validation is performed to test the calibrated parameters to see if the model can reproduce previous observations at different locations or for different time periods, without further adjustment.

Initial modeling parameters were previously calibrated and validated on a region-wide basis in the LSPC models developed to support Bacteria TMDL Project I (San Diego Water Board, 2007). To further validate these calibrated parameters for the Tecolote Creek watershed, additional comparisons of model output with measured flows and water quality from the Tecolote Creek watershed were performed. Twelve monitored storm events at the Mass Loading Station (see Figure C-2) between November 2001 and February 2005 were used to validate LSPC model performance for the Tecolote Creek watershed. These twelve storm events have high-frequency flow data and flow-weighted composite water quality data for comparison with model output (County of San Diego, 2005; Weston Solutions, Inc., 2006). Basic characteristics of the storm events are summarized in Table C-3.

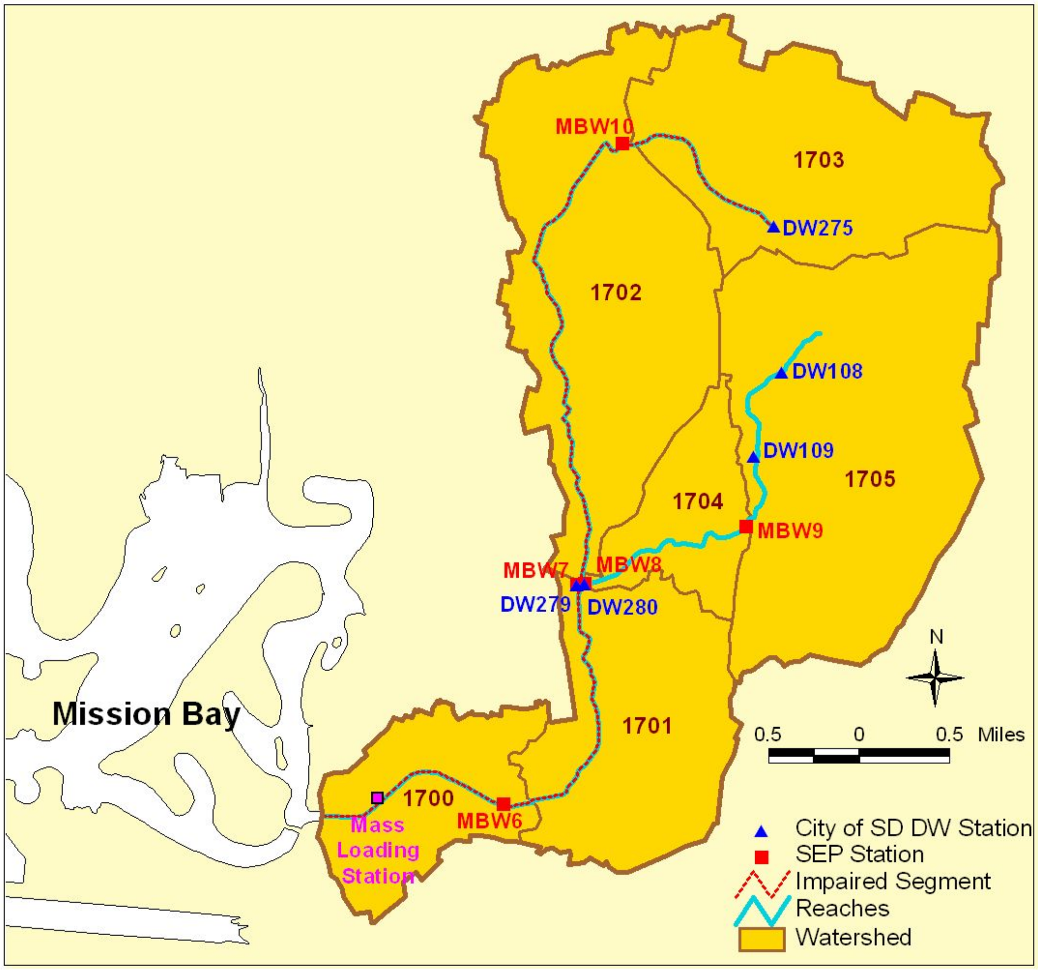

Figure C-2. Monitoring stations

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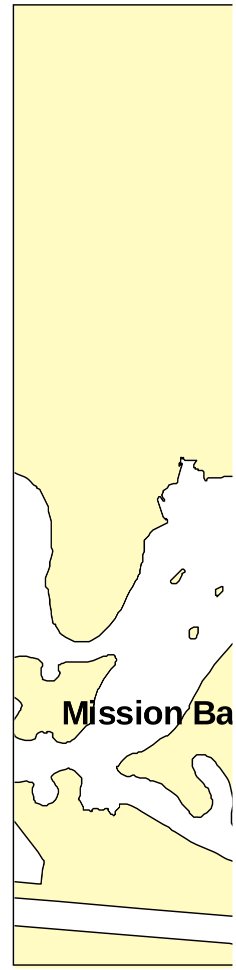

Table C-3. Summary of twelve monitored storm events

No	Start	End	Duration (hrs)	Max observed flow (cfs)	Rainfall (in/day)	Weather condition
1	11/29/2001 14:15	11/29/2001 22:05	7.83	33.0	0.12	Small storm
2	2/17/2002 12:00	2/17/2002 20:45	8.75	59.5	0.17	Small storm
3	3/7/2002 18:00	3/7/2002 23:45	5.75	55.2	0.03	Dry
4	11/8/2002 11:15	11/8/2002 22:35	11.33	194.8	0.13	Small storm
5	12/16/2002 00:00	12/16/2002 23:45	23.75	505.3	0.00	Dry
6	2/11/2003 09:00	2/11/2003 20:45	11.75	382.7	0.52	Medium storm
7	11/1/2003 05:50	11/1/2003 12:00	6.17	42.3	0.00	Dry
8	11/12/2003 07:40	11/12/2003 15:30	7.83	36.5	0.20	Small storm
9	2/3/2004 23:20	2/4/2004 05:50	6.50	393.8	0.19	Small storm
10	10/27/2004 03:25	10/27/2004 06:26	3.02	60,456.2	2.70	Extreme storm*
11	2/11/2005 02:50	2/11/2005 06:25	3.58	396.4	1.19	Medium storm
12	2/18/2005 04:05	2/18/2005 10:20	6.25	387.5	0.53	Medium storm

* This extreme observed flows are highly questionable. Additional data verification is required.

Small and medium storms were classified solely on the basis of daily rainfall measured at Lindbergh Field and not based on duration or flow. Specifically, if a storm resulted in between 0.1 and 0.5 inches of rainfall per day, the storm was classified as a small storm whereas a medium storm had between 0.5 and 2.0 inches of daily rainfall. In October 2004, data are presented for an extreme storm, which had very high rainfall and extraordinarily high stream flow. These reported flows are highly questionable and additional verification is required before they can be fully assessed.

If there was less than 0.1-inch of rainfall measured on the day of storm sampling, that day was classified as a “dry” weather condition. Although 0.1 inch can sometimes result in runoff, model prediction of storms less than 0.1 inch is often problematic due to rainfall being a poor predictor of runoff for such small storm events (Ackerman and Weisberg, 2003; Los Angeles Water Board, 2005a and 2005b). Three events were identified to occur on days categorized as dry conditions based on this criterion. These three events were not included in the model validation process due to uncertainty in flow/water quality prediction based on rainfall.

The presence of measured flows on these dry days suggests that data from the nearby NCDC weather station used to represent rainfall data in the watershed may not be accurate for all periods due to spatial variation in weather conditions. Ackerman and Weisberg (2003) reported that such small rainfall amounts were typically characteristic of isolated storm events that are difficult to identify based on current rain gage networks in Los Angeles watersheds. San Diego is expected to follow similar trends. Since these rainfall data were also used as the primary input to the model for prediction of stream flows, model error may be expected based on faulty representation of local rainfall in the watershed. The hydrology and water quality calibration and validation processes performed for the Tecolote Creek watershed model are described in the following subsections.

C.3.1 Hydrology Calibration and Validation

Hydrology is the first component of the model to be calibrated because an estimation of bacteria loading relies heavily on streamflow prediction. The hydrology calibration involves a comparison of model results to streamflow observations at selected locations and time periods. After running the model and comparing the model results with previous streamflow observations, key hydrologic parameters can be adjusted and additional model simulations are performed. This iterative process can be repeated until the simulated model results closely represent the stream system and reproduce previously observed streamflow patterns and magnitudes.

Model validation is then performed to test the calibrated parameters to see if the model can reproduce previous observations at different locations or for different time periods, without further adjustment. These validation results essentially confirm the appropriateness and applicability of the hydrologic parameters derived during the calibration process.

Regionally-calibrated, land use-specific hydrology parameter values developed while modeling the entire San Diego Region for Bacteria TMDL Project I (San Diego Water Board, 2007) were used to parameterize the Tecolote Creek watershed model. This single set of parameters was calibrated and validated over a diverse geographic (includes mountainous and coastal regions as well as highly urbanized and open areas) and temporal scale (includes extreme wet and dry conditions). A detailed description of this robust calibration, which included thirteen USGS gages throughout the San Diego Region, is described in the draft Bacteria TMDL Project I Technical Report (San Diego Water Board, 2007).

The regionally-calibrated modeling parameters were applied to the Tecolote Creek watershed model to perform the hydrology simulation. The general hydrology parameters remained unchanged in the Tecolote Creek watershed model; however, the Manning's coefficient (n) was altered slightly to adjust the timing and shape of the hydrographs. Model validation was performed through the comparison of hourly model-predicted flows with the previously observed storm hydrograph data collected at the Tecolote Creek Mass Loading Station (Figure C-1). Comparison of the modeled and observed flows for "small," "medium," and "extreme" monitored storm events (Table C-3) are presented in Figures C-3 through C-11. "Dry" events were not compared since the model predicted insignificant flows for these periods.

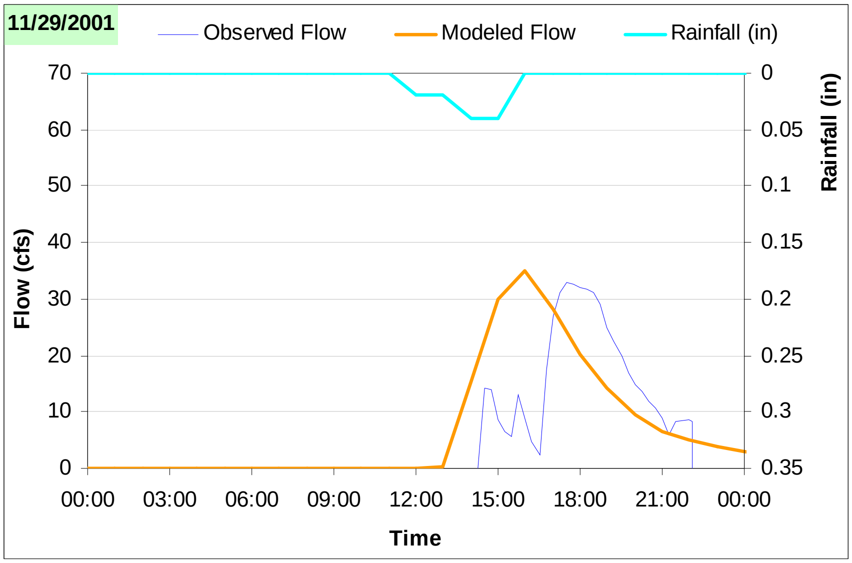

Figure C-3. Observed and modeled hydrographs – 11/29/2001

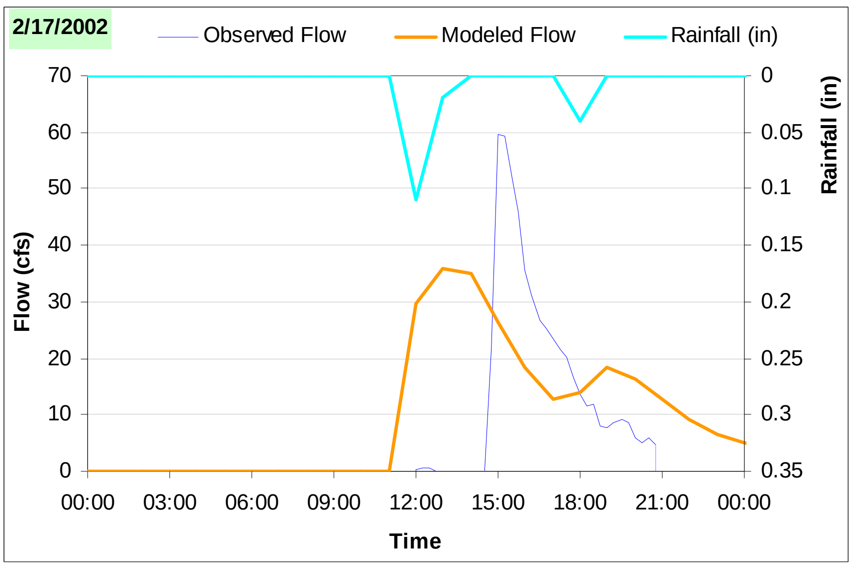

Figure C-4. Observed and modeled hydrographs – 2/17/2002

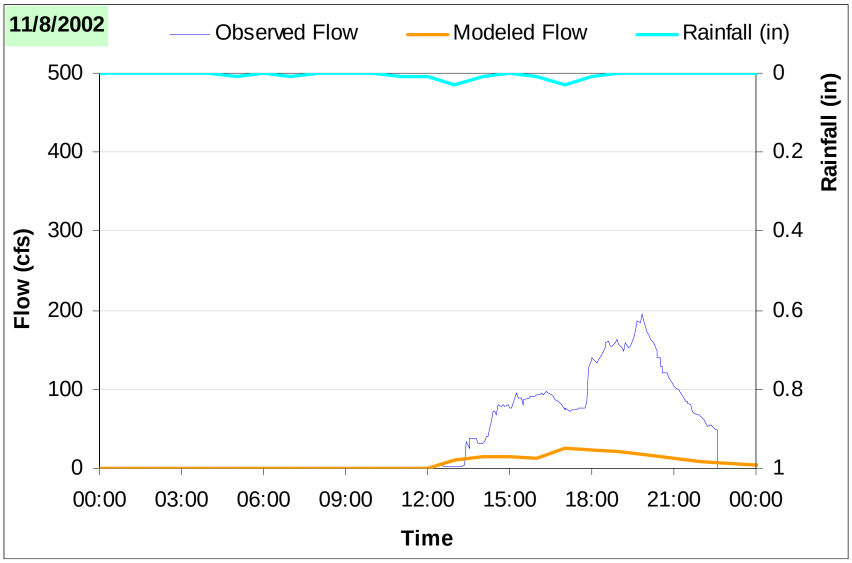

Figure C-5. Observed and modeled hydrographs – 11/8/2002

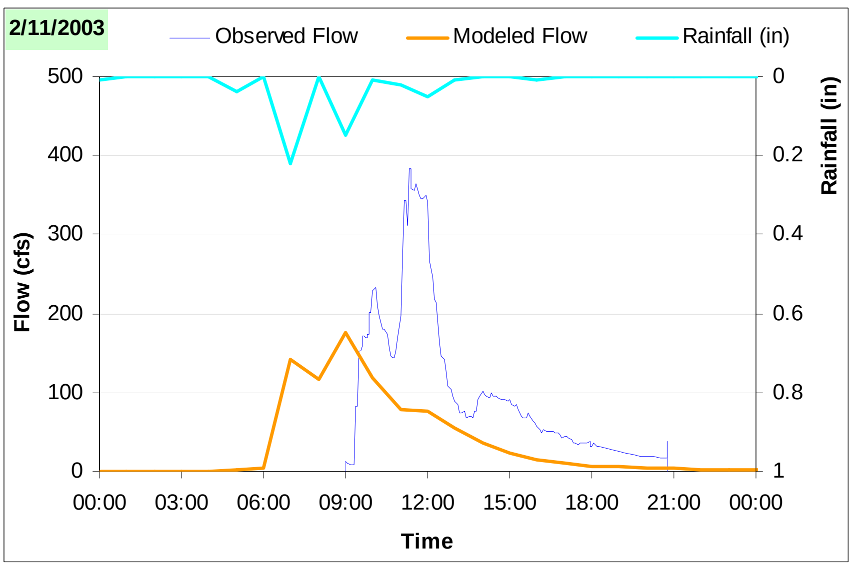

Figure C-6. Observed and modeled hydrographs – 2/11/2003

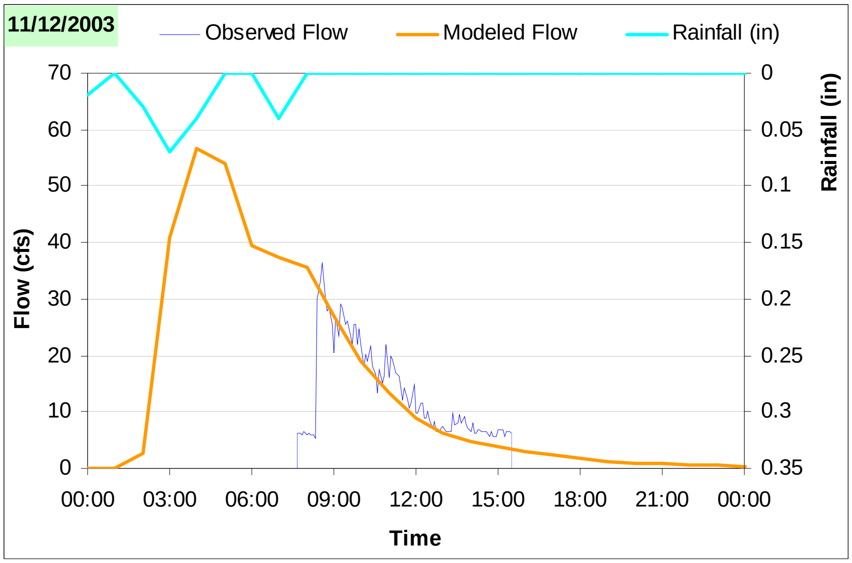

Figure C-7. Observed and modeled hydrographs – 11/12/2003

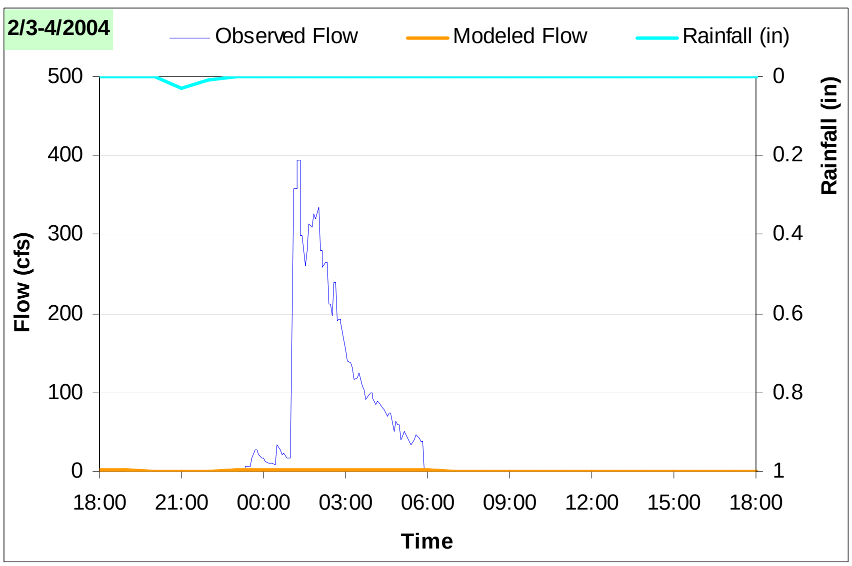

Figure C-8. Observed and modeled hydrographs – 2/3-4/2004

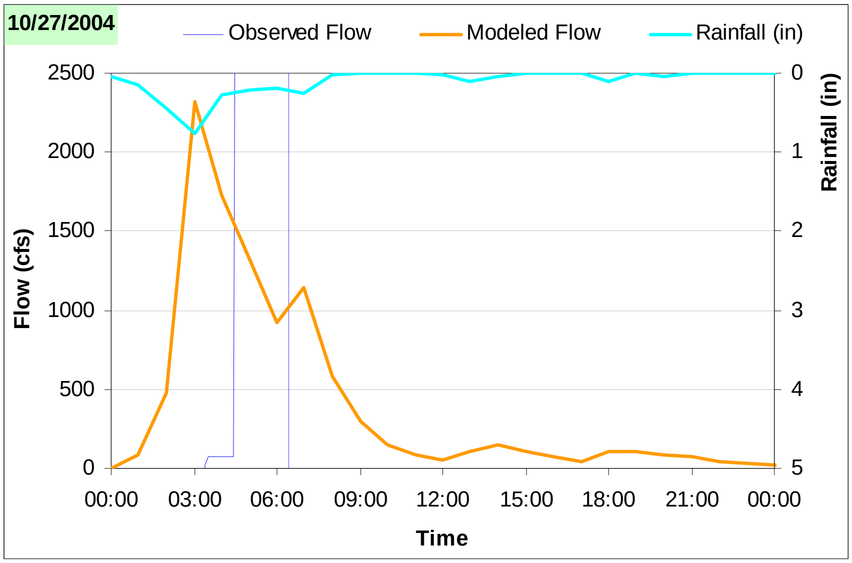

Figure C-9. Observed and modeled hydrographs – 10/27/2004

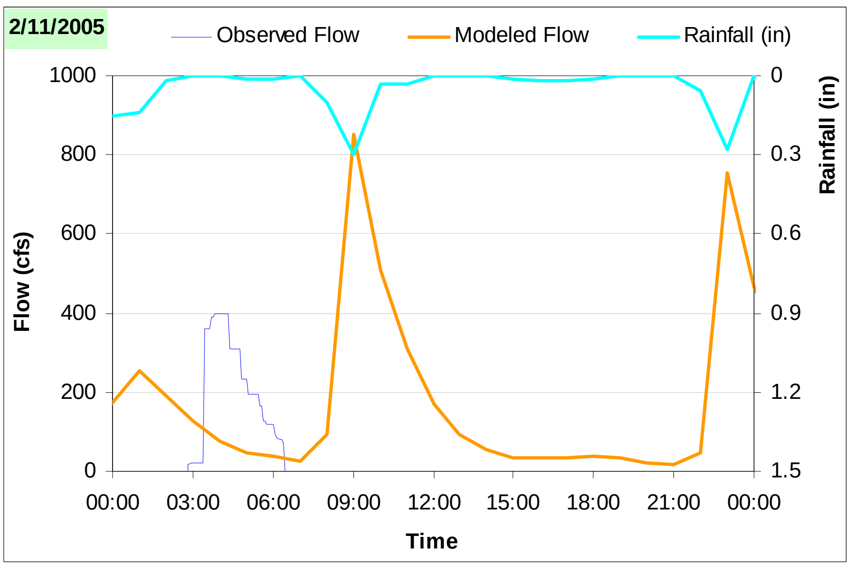

Figure C-10. Observed and modeled hydrographs – 2/11/2005

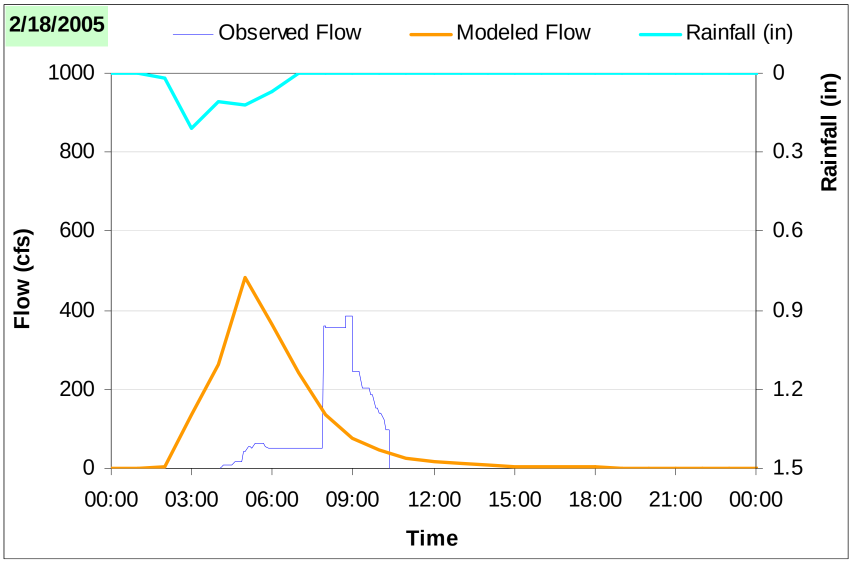

Figure C-11. Observed and modeled hydrographs – 2/18/2005

For some storms, the model did not predict significant flows, or the timing of the modeled flows did not match the observed storm period. However, rainfall data plotted on the secondary axis shows that modeled flows are controlled by the occurrence of measured rain used as model input. For some of these storms, not enough rainfall was recorded at the NCDC gage to provide volume for modeled flow prediction (Figures C-5 and C-8). This misrepresentation of flows is likely due to spatial variation in rainfall patterns, and localized storms that were not recorded at the weather gage. For other storms, the model predicted more storm volume than observed (Figures C-7, C-10, and C-11), which may be due to the opposite effect of localized rainfall at the location of the rainfall gage that did not occur in the watershed.

For the observed storm in Figure C-9, observed flows appear way too high than what is realistically possible (Note that for comparison, peak flows for San Diego River typically do not exceed 10,000 cfs), illustrating the potential for measurement errors that can further confound the validation process. In addition, the observed streamflow is based on a very small sub-hourly time interval, while the precipitation data at Lindbergh Field are hourly. This temporal discrepancy makes it difficult to compare storm hydrographs with hourly model output. Minor adjustments to Manning's coefficient were performed to provide better representation of timing of peak flows for those storms that included both modeled and observed flows.

Although these results are informative, they are generally inconclusive regarding the evaluation of the appropriateness of modeling parameters for simulation of hydrology in Tecolote Creek. Discrepancies in model results and observed data appear to result primarily from misrepresentation of rainfall for these periods. Therefore, these results lacked justification for modification of the previously calibrated and validated regional parameters.

C.3.2 Water Quality Validation and Sensitivity Analyses

After a model is calibrated and validated for hydrology, water quality model simulations are performed. As described above in section C.2.4, regionally-calibrated, land use-specific accumulation and maximum build-up rates for FC, TC, and ENT (Los Angeles Water Board, 2002) were used for the water quality model simulations. Since these values have been successfully applied to recent bacteria models in southern California, they were considered to be sufficiently calibrated. These values were validated for the San Diego Region in Bacteria TMDL Project I by comparing the model results with available monitoring data (San Diego Water Board, 2007).

Additional validation of the regionally-calibrated modeling parameters was performed for the Tecolote Creek watershed based on water quality monitoring data collected at the Mass Loading Station and other sample locations (see Figure C-2) (County of San Diego, 2005). Storm-specific composite sampling has been performed at the MLS station since 1993, and includes 35 monitored storm events. Grab samples for all of the storms monitored at the MLS station as well as several other wet sampling events associated with the Mission Bay Water Quality Survey were compared to hourly model output for FC, TC, and ENT. These results are presented in Figures C-12 through C-29. The graphs indicate that the model generally predicts bacteria concentrations within the observed ranges.

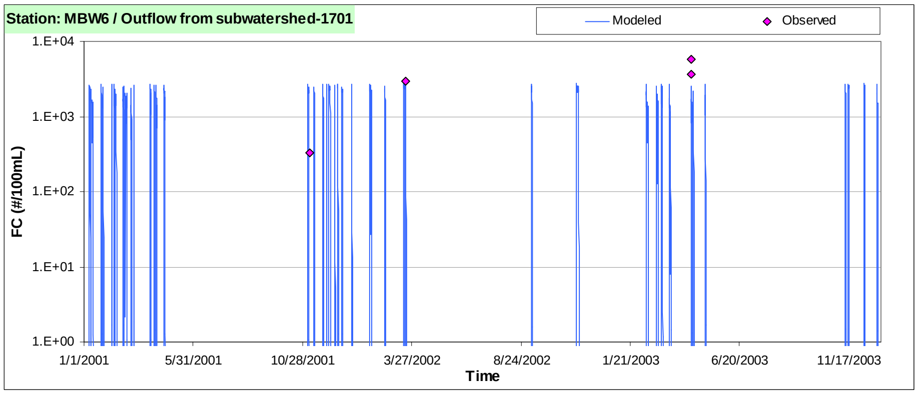

Figure C-12. Modeled and observed fecal coliform (FC) concentrations at MBW06

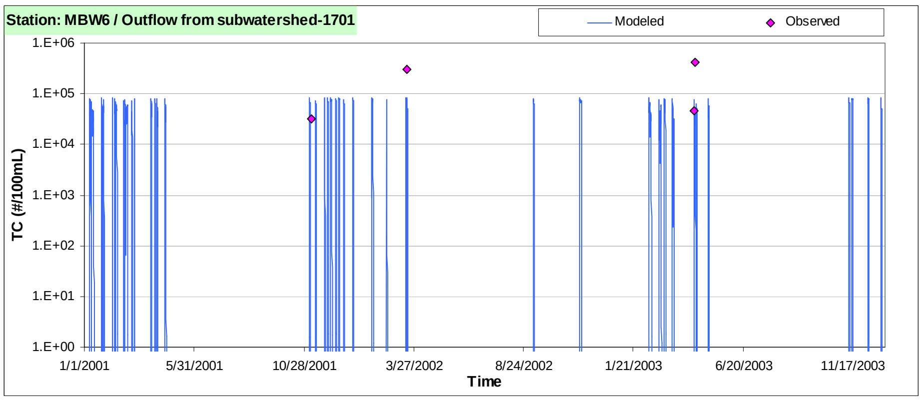

Figure C-13. Modeled and observed total coliform (TC) concentrations at MBW06

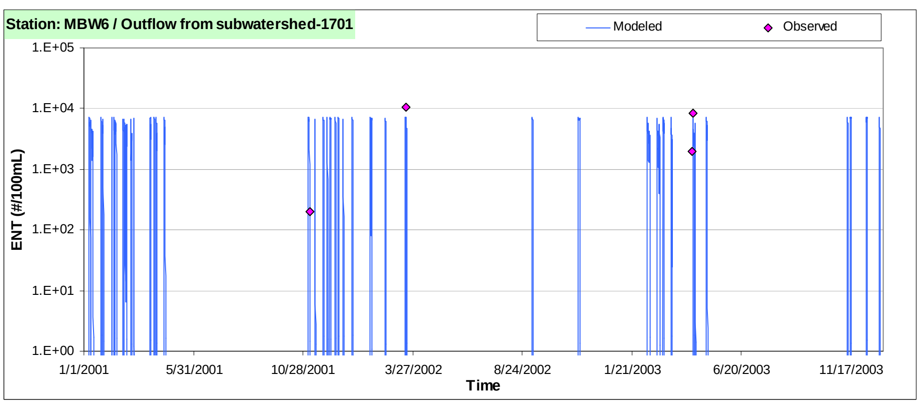

Figure C-14. Modeled and observed Enterococcus (ENT) concentrations at MBW06

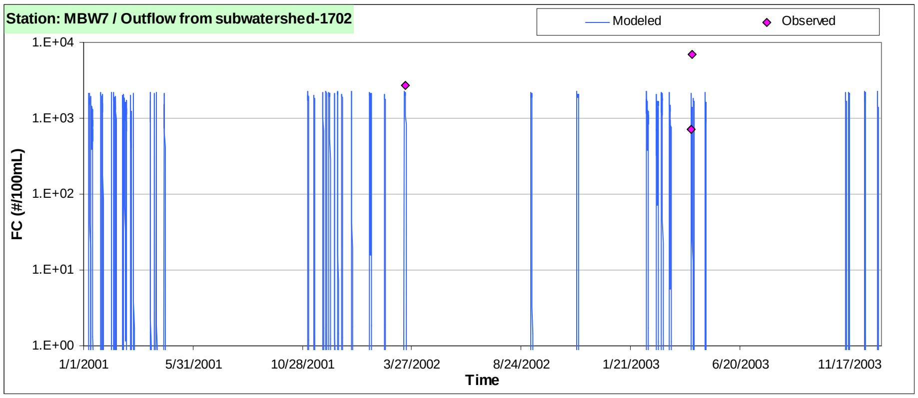

Figure C-15. Modeled and observed fecal coliform (FC) concentrations at MBW07

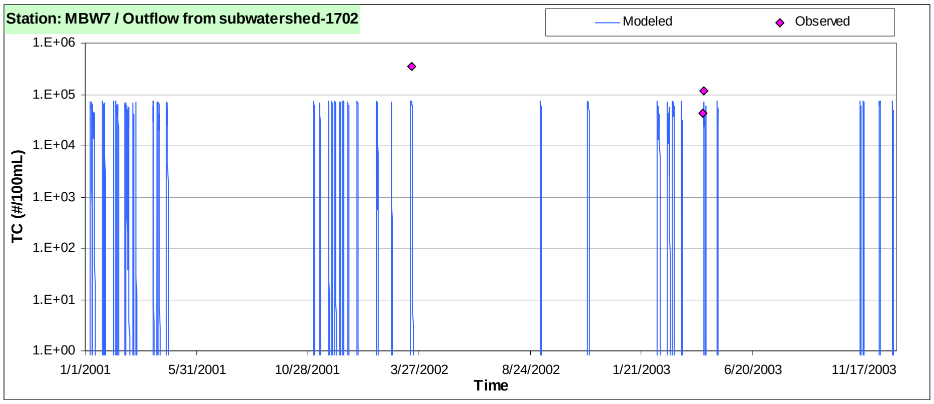

Figure C-16. Modeled and observed total coliform (TC) concentrations at MBW07

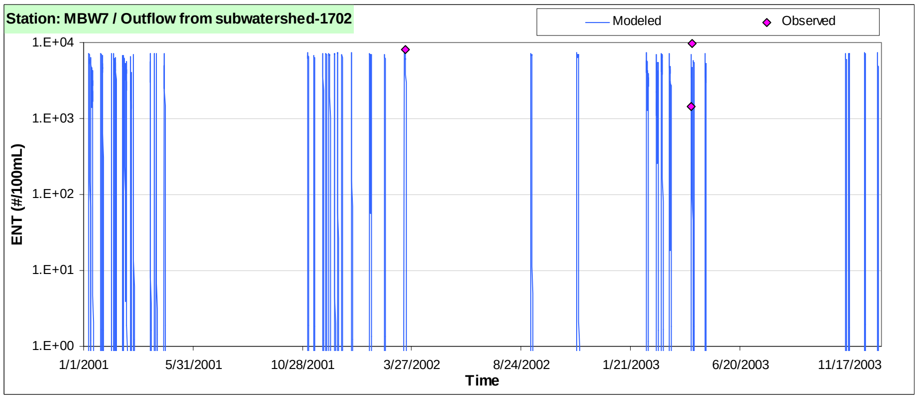

Figure C-17. Modeled and observed Enterococcus (ENT) concentrations at MBW07

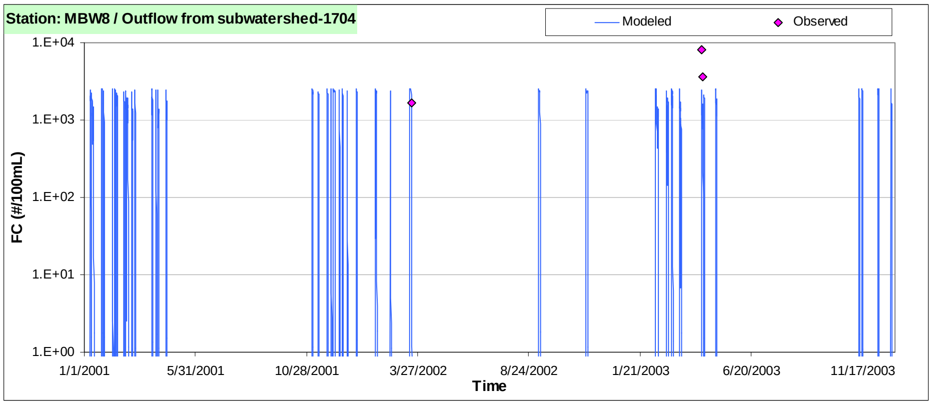

Figure C-18. Modeled and observed fecal coliform (FC) concentrations at MBW08

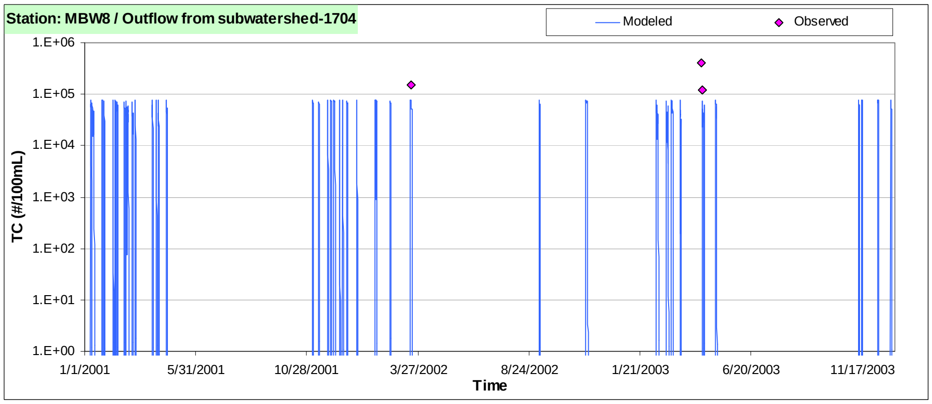

Figure C-19. Modeled and observed total coliform (TC) concentrations at MBW08

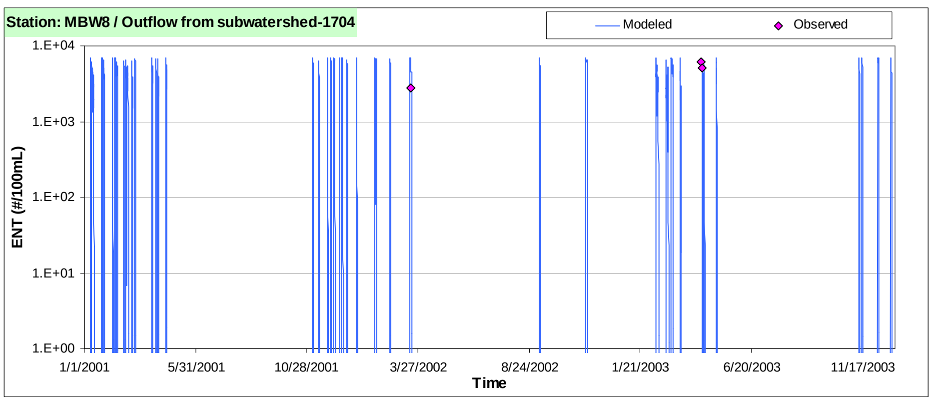

Figure C-20. Modeled and observed Enterococcus (ENT) concentrations at MBW08

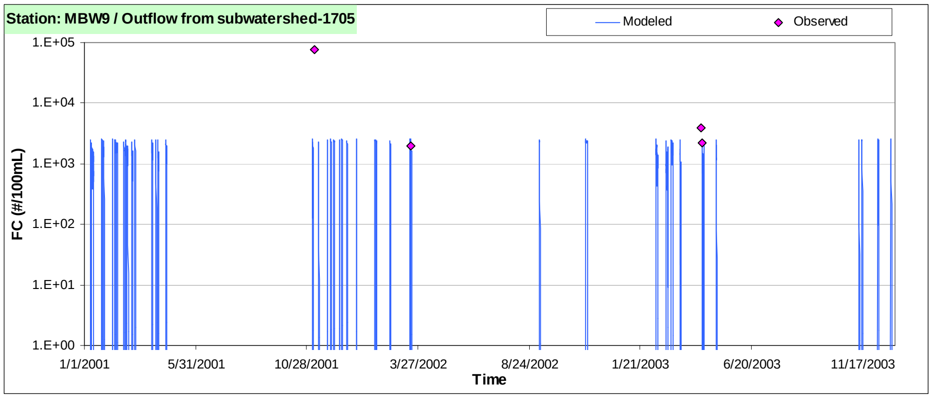

Figure C-21. Modeled and observed fecal coliform (FC) concentrations at MBW09

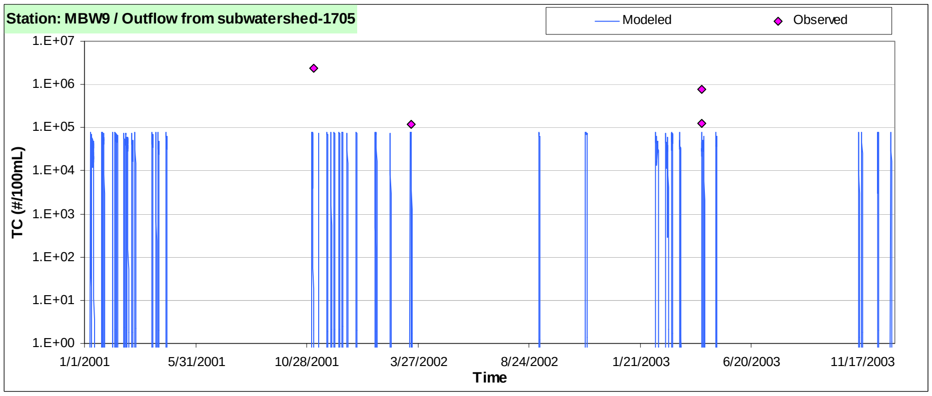

Figure C-22. Modeled and observed total coliform (TC) concentrations at MBW09

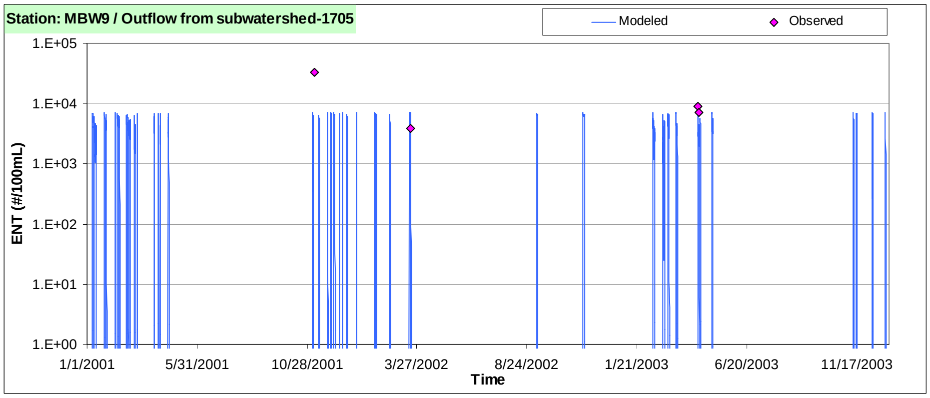

Figure C-23. Modeled and observed Enterococcus (ENT) concentrations at MBW09

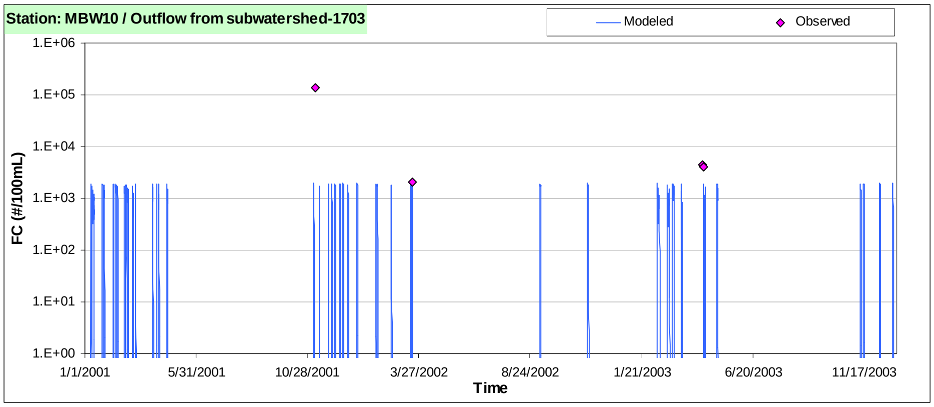

Figure C-24. Modeled and observed fecal coliform (FC) concentrations at MBW10

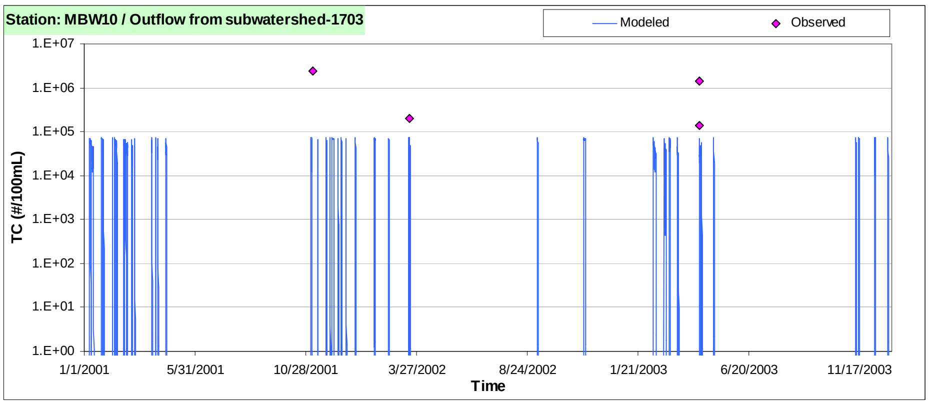

Figure C-25. Modeled and observed total coliform (TC) concentrations at MBW10

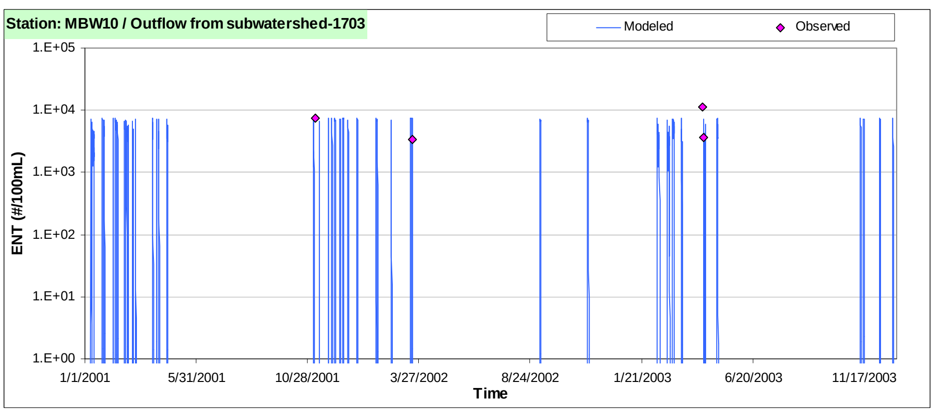

Figure C-26. Modeled and observed Enterococcus (ENT) concentrations at MBW10

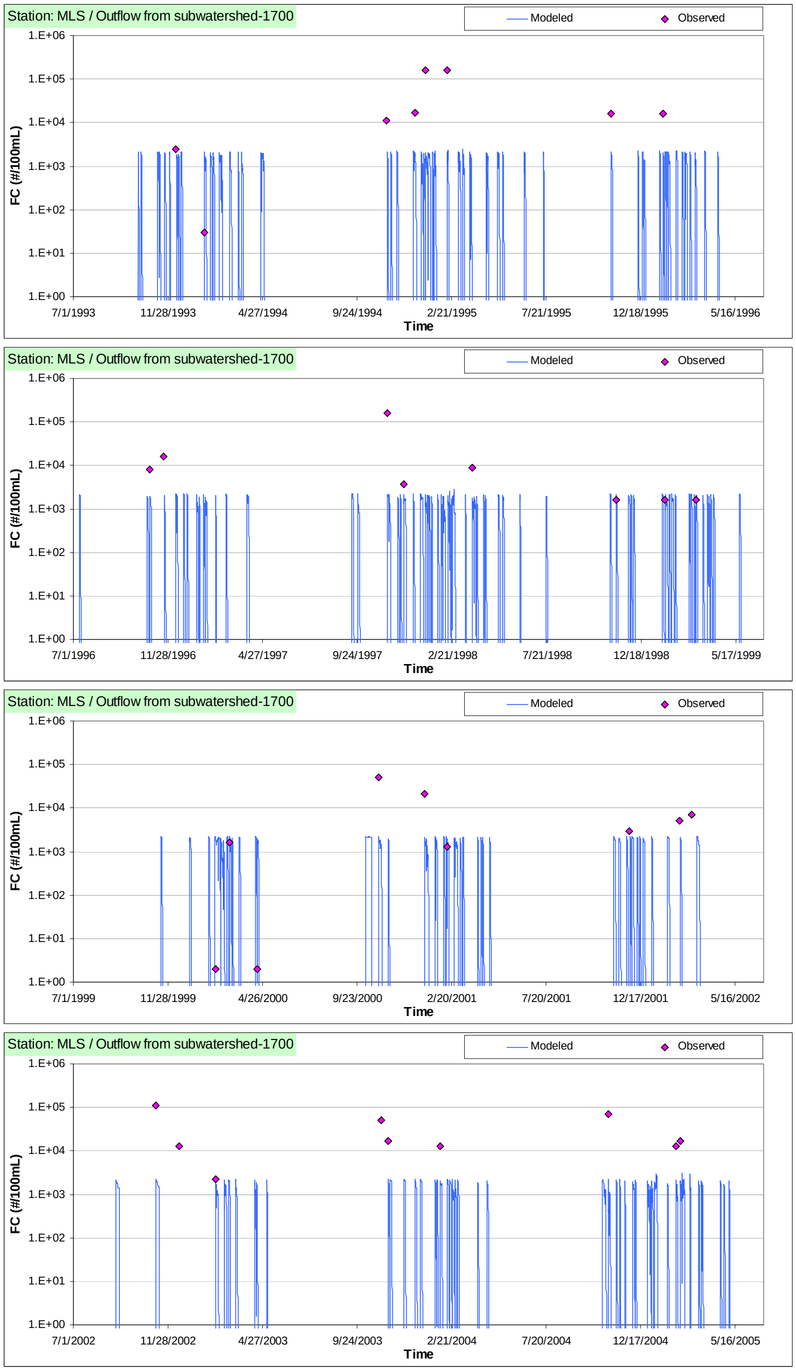

Figure C-27. Modeled and observed fecal coliform (FC) concentrations at the MLS

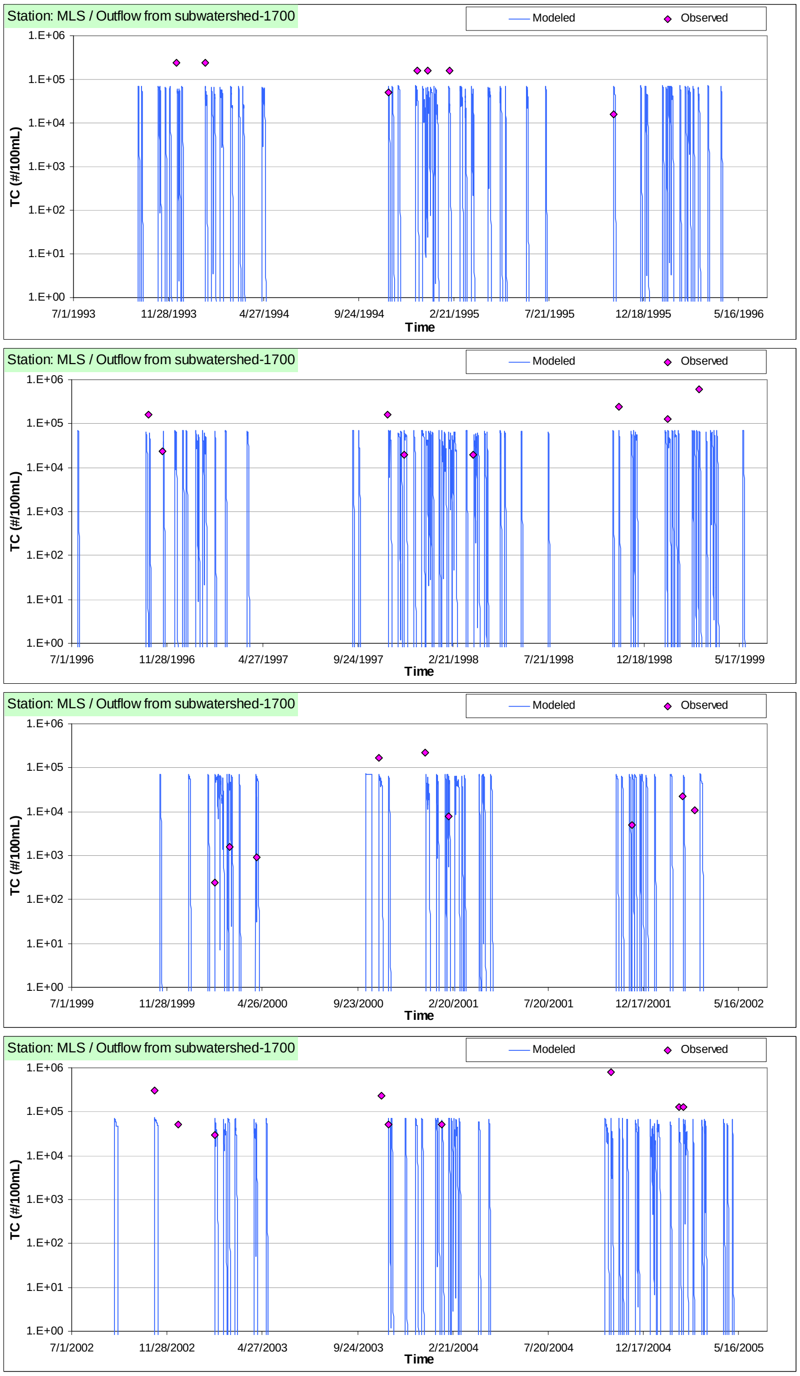

Figure C-28. Modeled and observed total coliform (TC) concentrations at the MLS

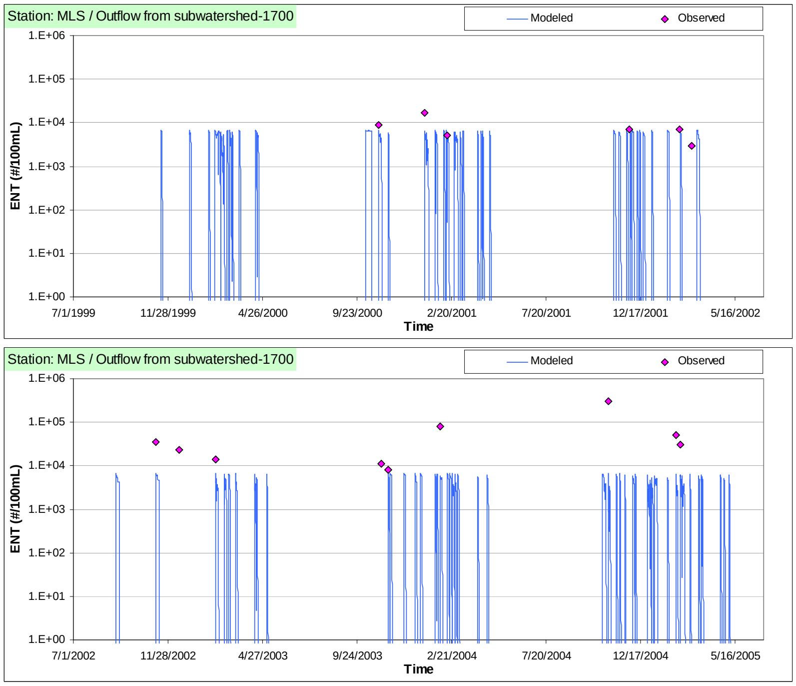

Figure C-29. Modeled and observed Enterococcus (ENT) concentrations at the MLS

In addition to the time series comparisons, modeled pollutographs are presented for several storms at the Mass Loading Station. Corresponding monitored streamflow data were collected only for the last 12 storm events at the Mass Loading Station (Table C-3). Since modeling of storm events has shown to be impacted by the accuracy of rainfall data used as model input (see section C.3.1), water quality validation was only performed for those latter monitored storms when model output sufficiently represent the storm.

From the hydrologic modeling results presented in the previous section, several general observations between the observed and the modeled flows were found. In some cases, much higher flows were observed than modeled flows while there was almost zero or an insignificant amount of rainfall recorded (e.g., events in Figures C-5, C-8, and C-9). In some events, the modeled flows occurred earlier than the observed flows (e.g., events in Figures C-6 and C-7). After all of the storms were reviewed, four were selected for validation of water quality: 11/29/2001 (Figure C-3), 2/17/2002 (Figure C-4), 2/11/2003 (Figure C-6), and 2/18/2005 (Figure C-11). Modeled pollutographs and hydrographs at the Mass Loading Station (see Figure C-2) for the four selected storms are presented in Figures C-30 through C-33.

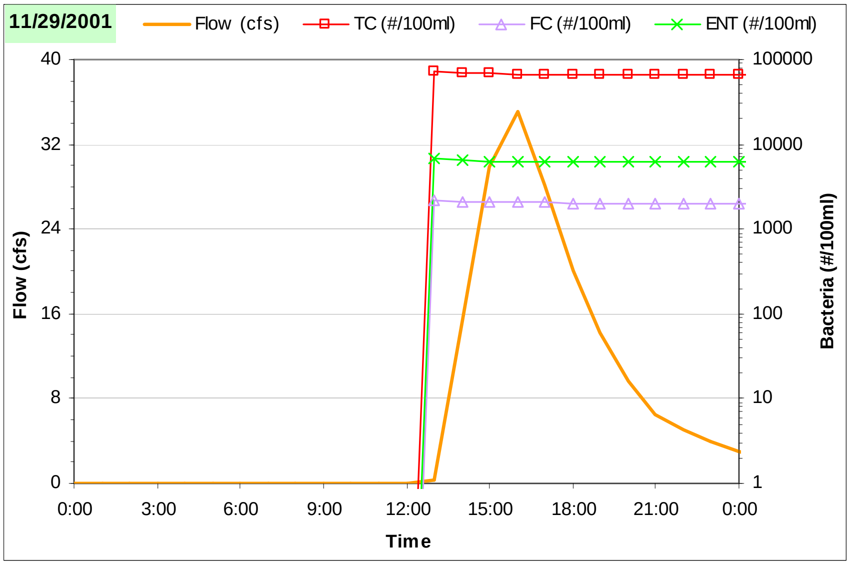

Figure C-30. Modeled pollutographs for bacteria – 11/29/2001

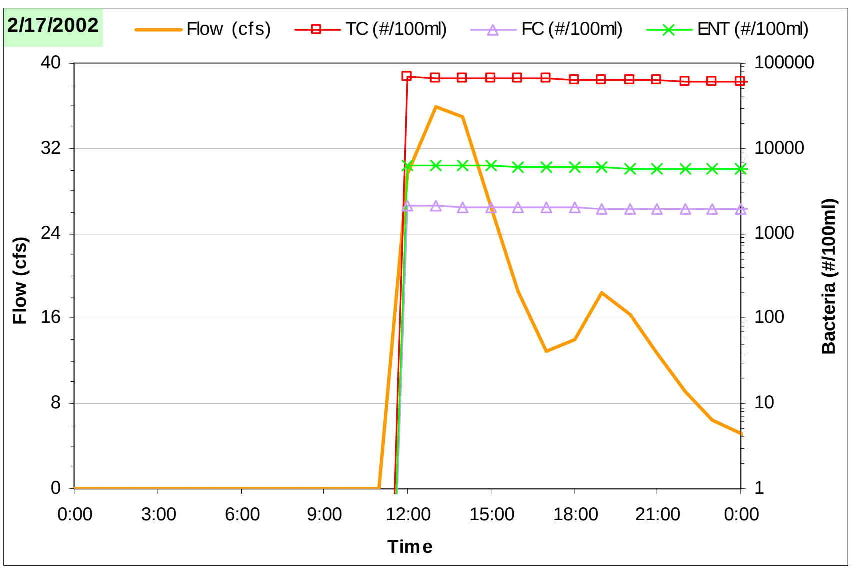

Figure C-31. Modeled pollutographs for bacteria – 2/17/2002

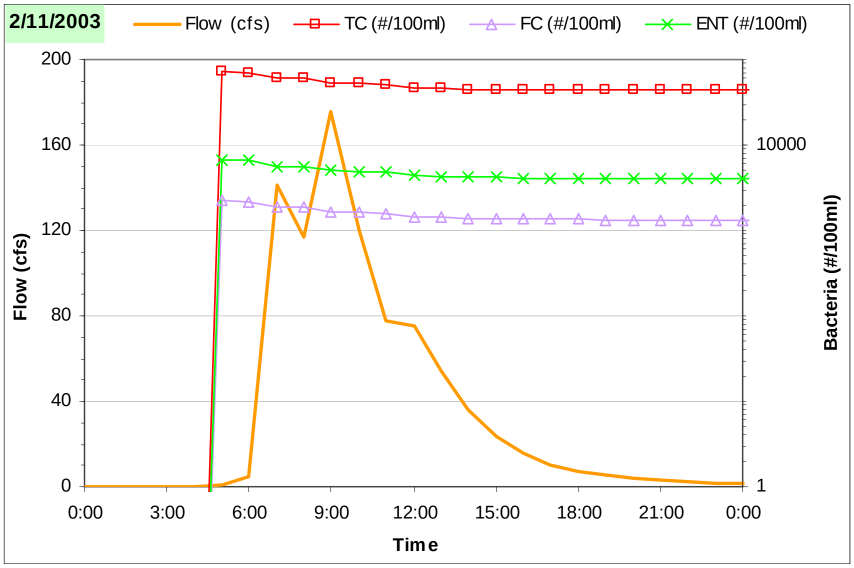

Figure C-32. Modeled pollutographs for bacteria – 2/11/2003

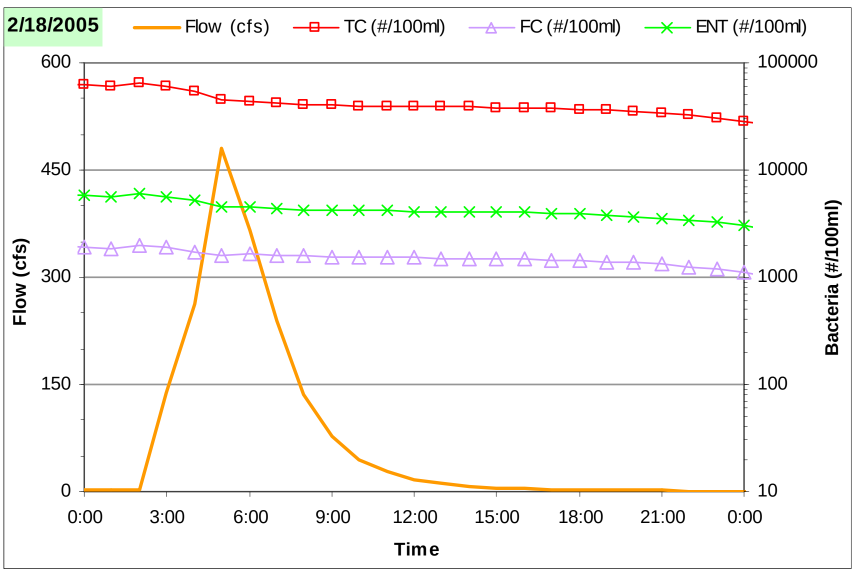

Figure C-33. Modeled pollutographs for bacteria – 2/18/2005

Monitoring data at the Mass Loading Station are reported as storm composite concentrations. For comparison of model results with these observed storm-specific concentrations, event mean concentrations (EMCs) were calculated from model output. In order to calculate the EMCs from model output, the following equations were used:

$$V_i = \frac{(Q_{i-1} + Q_i)}{2}[\mathrm{ft}^3/\mathrm{s}] \cdot 1[\mathrm{hr}] \cdot 3600[\mathrm{s/hr}] \cdot 28.31685[\mathrm{L/ft}^3] \qquad (1)$$

$$\#_i = \frac{(\#_{i-1} + \#_i)}{2}[\#/100\,\mathrm{ml}] \cdot V_i[\mathrm{L}] \cdot 10[100\,\mathrm{ml/L}] \qquad (2)$$

$$EMC = \frac{\sum \#_i}{\sum V_i[\mathrm{L}] \cdot 10[100\mathrm{ml/L}]} \qquad (3)$$

where V = flow volume (L); Q = modeled flow rate (ft^3/s); # = number of bacteria (numbers of bacteria per 100 ml, #/100ml).

The storm composite sample concentrations and the calculated EMCs from model output are presented in Figures C-34 through C-36 for FC, TC, and ENT, respectively.

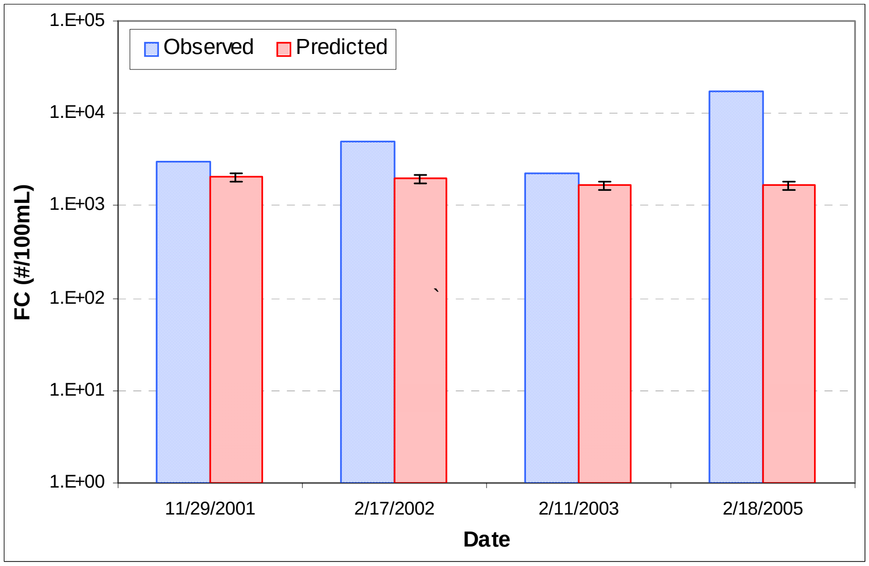

Figure C-34. Observed versus modeled fecal coliforms (FC)

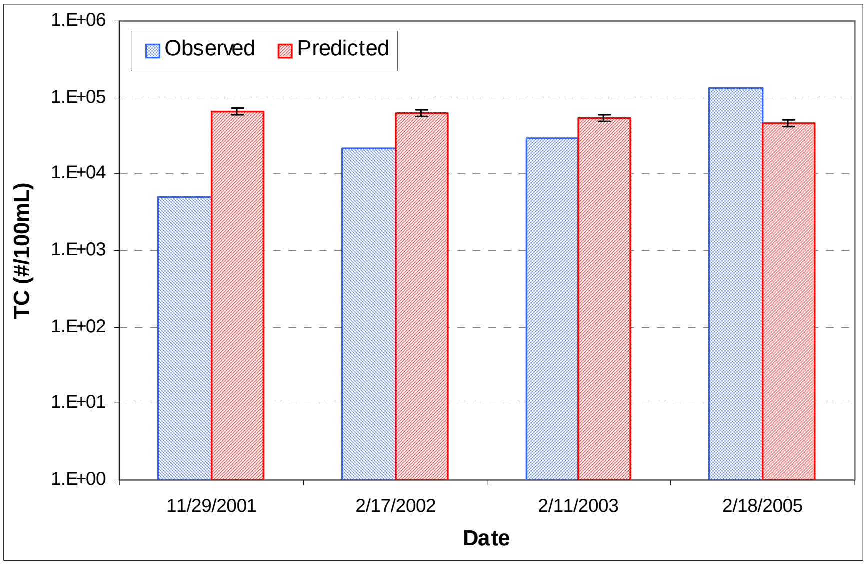

Figure C-35. Observed versus modeled total coliforms (TC)

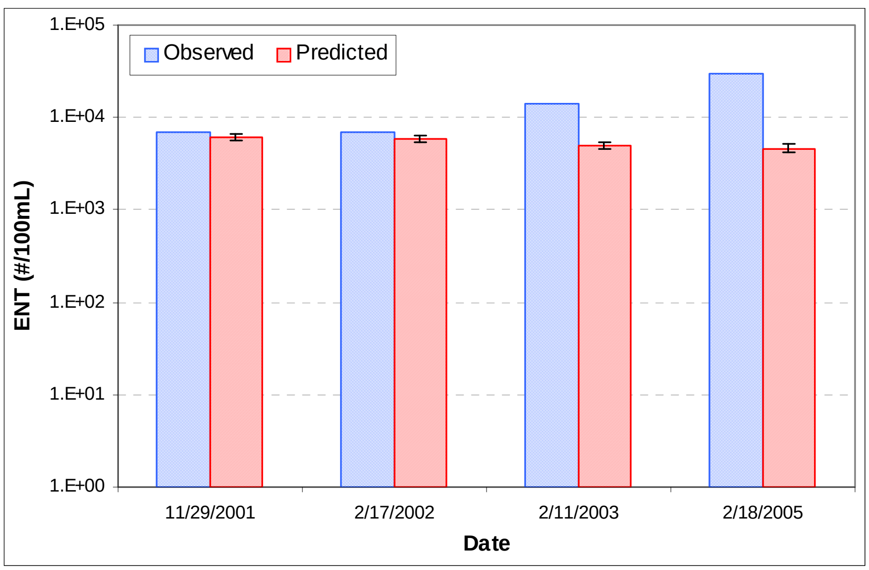

Figure C-36. Observed versus modeled Enterococcus (ENT)

The water quality modeling results show that the modeled EMCs are both above and below observed storm composite concentrations. In general, the trend in bacteria concentrations appear similar and mostly within an order of magnitude. Differences in model predictions and observed bacteria levels can be further complicated by the difference in modeled versus observed flows. Although the four storms analyzed above were shown to be generally similar between modeled and observed conditions, the differences in distribution and timing of the hydrographs and the resulting storm volumes can impact water quality comparisons. Regardless, results of this validation process did not provide just cause for further calibration based on adjustment of regional model build-up rates for bacteria.

Sensitivity analyses were performed for comparison with model results. These analyses included modifying the ACQOP and SQOLIM water quality parameters and re-running the model. ACQOP is the accumulation rate of the pollutant on the land surface and SQOLIM is the maximum build up of the pollutant on the land surface. Using these parameters, the pollutant builds up on the land surface at the constant accumulation rate until it either washes off during a precipitation event or the pollutant level reaches the maximum build up on the land surface. The ACQOP and SQOLIM values, which were part of the regionally calibrated parameters provided by SCCWRP, vary by land use and are extremely important parameters for water quality simulations. To assess their sensitivity on model output, model runs were performed using ACQOP and SQOLIM values ten percent higher and ten percent lower than the regionally calibrated values. The ten percent sensitivity factor was arbitrarily selected and is not based on previous modeling efforts or standard guidelines. These analyses should only be used as a relative comparison of parameter sensitivity on bacteria concentrations and not as an explicit margin of safety. The results of these analyses are represented by the error bars in Figures C-34 through C-36. While the ACQOP and SQOLIM parameters are the driving force behind the bacteria levels output by the model, the error bars indicate that a ten percent difference in their values does not significantly change the resulting event mean concentrations.

C.4 Summary and Conclusions

Wet weather streamflow and water quality modeling has been performed for the Tecolote Creek watershed. Previous regionally-calibrated parameters for hydrology and water quality simulations from Bacteria TMDL Project I (San Diego Water Board, 2007) were used in the development of an LSPC model of the Tecolote Creek watershed. These parameters have been widely used throughout the southern California area (Los Angeles Water Board, 2002; San Diego Water Board, 2007; Tetra Tech, Inc, 2005b), including the San Diego Region.

In order to validate LSPC model performance for the Tecolote Creek watershed, twelve monitored storm events between November 2001 and February 2005 were compared with regionally-calibrated model simulation results. Localized rainfall patterns were observed to impact the ability of the model to predict specific storms with accuracy. In addition, misrepresentative rainfall data used as model input appears to limit the accuracy of the model for predicting hourly flows. As a result, prediction of average daily flows is recommended for loading assessment and TMDL calculation.

Because of differences in the timing, volume, and peak of the observed and modeled hydrographs, four monitored storm events were selected for water quality comparison. Although some differences in observed and modeled water quality were shown for the limited number of storms validated, not enough information or detail were provided to justify adjustment and re-calibration of the regionally calibrated/validated modeling parameters. For all storms monitored and used for comparison to model output, misrepresentation of rainfall appeared to impact the model more than any clear error with modeling parameters. The modeling parameters were originally calibrated by SCCWRP for each land use based on corresponding data collected for rainfall, flow, and water quality at each site, hence reducing any impact from variability in input or comparison data that could influence calibration. Although the data for Tecolote Creek is detailed in terms of flows and water quality, the clear mismatch of rainfall data prevents justification of further calibration of modeling parameters. In addition, data collected in Tecolote Creek are impacted by runoff from multiple land uses, making it very difficult to isolate and independently calibrate land-use-specific modeling parameters. Therefore, although useful for verification of the model, no further model calibration was performed.